Power Oscillation Damping Controller Using STATCOM with Energy Storage

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ABSTRACT:

This paper presents the design of an adaptive power oscillation damping (POD) controller for a static synchronous compensator (STATCOM) equipped with energy storage. The proposed method is effective in increasing the damping of the system at the desired frequencies. First, the impact of active and reactive power injection into the power system will be carried out using a simple two-machine system model. A control strategy that optimizes active and reactive power injection at various connection points of the STATCOM will be derived using the simplified model. The effectiveness of the proposed control method to provide power oscillation damping irrespective of the connection point of the device and in the presence of system parameter uncertainties will be verified through simulation and results.

Keywords — **Power oscillation damping, STATCOM, Storage system, Reactive power injection.**

I INTRODUCTION

STATCOM has been applied both at distribution level to mitigate power quality phenomena and at transmission level for voltage control and power oscillation damping (POD) [1]–[3]. Although it is used for reactive power injection , by equipping the STATCOM with an energy storage connected to the dc-link of the converter, a more flexible control of the transmission system can be achieved [4], [5]. An installation of a STATCOM with energy storage is already found in the U.K. for power flow management and voltage control [6]. The introduction of wind energy and other distributed generation will pave the way for more energy storage into the power system and auxiliary stability enhancement function is possible from the energy sources [7]. Because injection of active power is used temporarily during transient, incorporating the stability enhancement function in systems where active power injection is primarily used for other purposes [8].

Low-frequency electromechanical oscillations (typically in the range of 0.2 to 2 Hz) are common in the power system and are a cause for concern regarding secure system operation, especially in a weak transmission system [9]. In this regard, FACTS controllers, both in shunt and series configuration, have been widely used to enhance stability of the power system [1]. In the specific case of shunt connected FACTS controllers [STATCOM and static var compensator (SVC)], first swing stability and POD can be achieved by modulating the voltage at the point of common coupling (PCC) using reactive power injection. However, one drawback of the shunt configuration for this kind of applications is that the PCC voltage must be regulated within specific limits (typically between 10% of the rated voltage), and this reduces the amount of damping that can be provided by the compensator. Moreover, the amount of injected reactive power needed to modulate the PCC voltage depends on the short circuit impedance of the grid seen at the connection point. Injection of active power, on the other hand, affects the PCC-voltage angle (transmission lines are effectively reactive) without varying the voltage magnitudesignificantly.

In this paper, a control strategy for the E-STATCOM when used for POD will be investigated. The control strategy optimizes the injection of active and reactive power to provide uniform damping at various locations in the power system. It will be shown that the implemented control algorithm is robust against system parameter uncertainties. For this, a modified recursive least square (RLS)-based estimation algorithm as described in [13], [14] will be used to extract the required control.

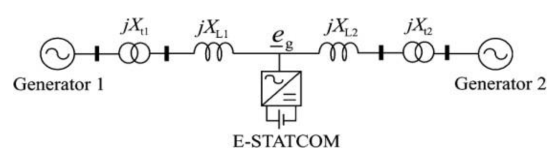

Fig. 1. Simplified two-machine system withE-STATCOM.

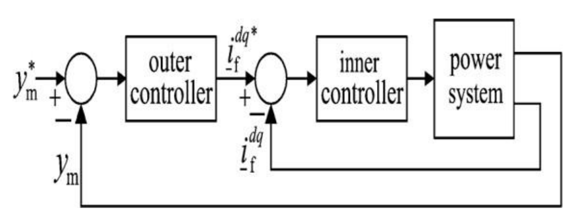

Fig. 2. Block diagram of the control of E-STATCOM.

The impact of FACTS-gadgets is accomplished through exchanged or controlled shunt remuneration, arrangement pay or stage move control. The gadgets work electrically as quick present, voltage or impedance controllers. The power electronic permits short response times down to far underneath one moment.

II STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

The STATCOM is a strong state-based power converter rendition of the SVC. Working as a shunt-associated SVC, its capacitive or inductive yield streams can be controlled freely from its terminal AC transport voltage. Due to the quick exchanging normal for power converters, STATCOM gives significantly speedier reaction when contrasted with the SVC. Likewise, in case of a quick change in framework voltage, the capacitor voltage does not change immediately; in this manner, STATCOM viably responds for the coveted reactions. For instance, if the framework voltage drops for any reason, there is an inclination for STATCOM to infuse capacitive energy to bolster the plunged voltages. STATCOM is able to do high powerful execution and its remuneration does not rely on upon the normal coupling voltage. In this manner, STATCOM is exceptionally successful amid the power framework unsettling influences. Additionally, much research affirms a few focal points of STATCOM. These points of interest contrasted with other shunt compensatorsinclude:

- Weight, size and cost lessening
- Equality of slacking and driving yield
- Precise and ceaseless receptive powercontrol with quick reaction
- Possible dynamic consonant channelcapacity

This section depicts the structure, fundamental working rule and qualities of STATCOM. Moreover, the idea of voltage source converters and the comparing control methods are outlined.

A) Structure of STATCOM

Essentially, STATCOM is included three principle parts (as observed from Fig. 3): a voltage source converter (VSC), a stage up coupling transformer, and a controller. In a high- voltage framework, the spillage inductances of the progression up power transformers can work as coupling reactors. The principle reason for the coupling inductors is to sift through the present consonant parts that are created for the most part by the throbbing yield voltage of the powerconverters.

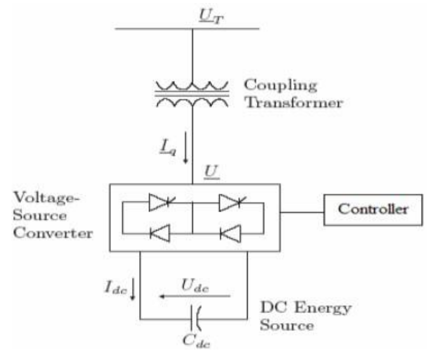

Fig.3. Reactivepower generation by STATCOM.

III ACTIVE POWER COMPENSATION OF STATCOM WITH ENERGY STORAGE SYSTEMS

A STATCOM is a second generation FACTS controller based on a self-commutated solid- state voltage source inverter. It has been used with great success to provide reactive power/voltage control and transient stability enhancement. A STATCOM, however, can only absorb/inject reactive power, and consequently is limited in the degree of freedom and sustained action in which it can help the power grid. The addition of energy storage allows the STATCOM to inject and/or absorb active and reactive power simultaneously, and therefore provides additional benefits and improvements in the system. The voltage source inverter front- end of a STATCOM can be easily interconnected with an energy storage source. This viable technology is applicable for high power utility and defense applications. With Energy Storage Systems (ESS), STATCOM can provide the ride through over outages and voltage collapses. The VSC may operate as a backup power supply if energy storage capability is available on the DC side, the development of energy storage elements reduces voltage quality problems related to voltage sags and interruptions by serving as a driving force. Power oscillation occurs when there is a trip 168 of transmission lines, loss of generation, or large changes in electric load. The possible benefits of integrating ESS into a STATCOM are Compensation of sudden active load changes for the reduction of voltage phase jumps in weak networks Compensation of a cyclic load for the improvement of the power quality at the PCC.

A) Energy Storage System

Recent developments and advances in energy storage and power electronics technologies are making the application of energy storage technologies a viable solution for modern power applications. Viable storage technologies include batteries, flywheels, ultra capacitors, and superconducting energy storage systems. These technologies are now seen more as a tool to enhance system stability, aid power transfer and improve power quality in power systems. ESS can increase system reliability and dynamic stability, improve power quality and enhance transmission capacity of the transmission grid in a high power application. For a high power application, the use of short-term (cycles to seconds) energy storage integrated with a FACTS controller, could offer the following distinct advantages: Provide system damping, while maintaining constant voltage following a disturbance, Provide additional damping in situations where the dynamic reactive power provided by traditional FACTS controllers with similar ratings is inadequate. Alternatively, it could provide the same amount of damping at less cost Damping of oscillation, by repeatedly interchanging small amounts of real power with the system, would be an excellent ESS application Provide energy to maintain the speed of locally connected induction motors during a power system disturbance. This may prevent a voltage collapse in areas where there is a large concentration of induction motors that would otherwise stall The voltage sag mitigation techniques investigated by the aforementioned works aim to reduce the impact of voltage sags on some particularly protected loads.

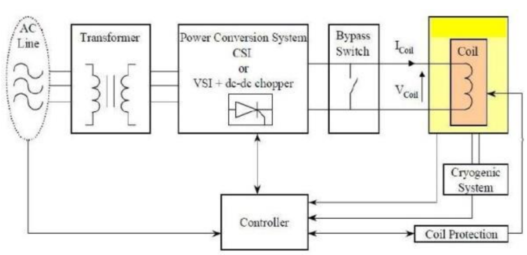

Fig.4 Basic components of a SMESsystem

This work will instead describe control strategies for a STATCOM with ESS to provide high speed real and reactive power control and enhance the power flow in a line with cyclic loads. The study is focused on the voltage fluctuations caused by sudden changes in the load connected at the PCC. The STATCOM does not employ capacitor or reactor banks to produce reactive power but is used to maintain a constant DC voltage in order to allow the operation of the voltage source converter. The converter/SMES system is highly efficient, as there is no energy conversion from one form to another. Converters may produce harmonics on the AC bus and in the terminal voltage of the coil. Using higher pulse converters harmonics can be reduced. For this purpose a 48-pulse VSC is chosen for the proposed work.

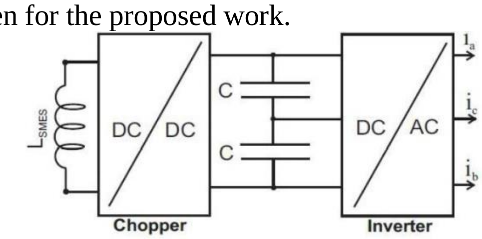

Fig.5 PCS for SMES-based FACTS devices.

In SMES, the DC current flowing through a superconducting wire in a large magnet creates the magnetic field and stores energy in the magnetic field. The inductively stored energy and the rated power for SMES devices can be expressed as follows: where L is the inductance of the coil, I is the DC current flowing through the coil and V is the voltage across the coil. When DC current flows through the SMES coil, it is either charged or discharged depending upon the polarity of the applied voltage. When zero voltage is applied, the SMES coil is in standby mode, maintaining constant DC current.

IV SIMULATION RESULTS AND ANALYSIS

The implemented system is rated 20/230kV, 900 MVA, total series reactance of 1.665 p.u. P=400 MW and inertia constants. Leakage reactance of transformers 0.15 p.u. and transient impedance of generators 0.3 p.u. By creating a three phase fault at transmission line and E-STATCOM is connected at various points and simulation results were carried out by using simulink/MATLAB software. The simulation results for both PI and E-STATCOM are presented.

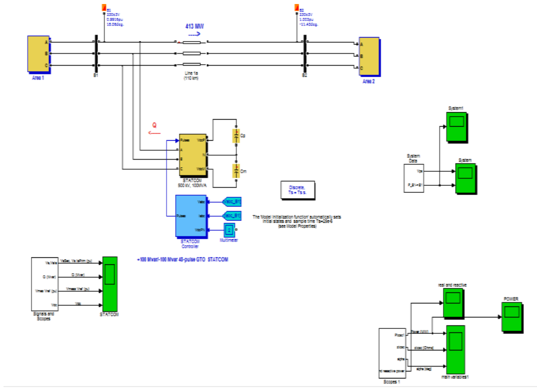

Fig. 6. Simulation block diagramfor the system with E-STATCOM.

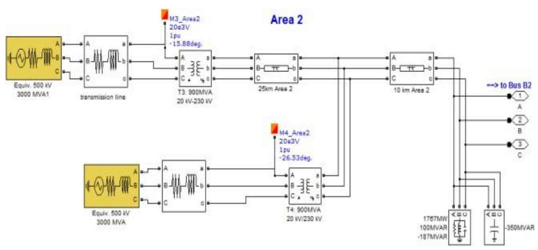

Fig. 7 Simulation block diagram for theAREA 1.

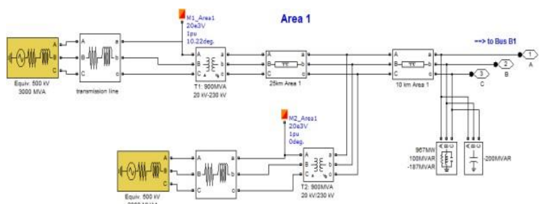

Fig. 8 Simulation block diagram for theAREA 2.

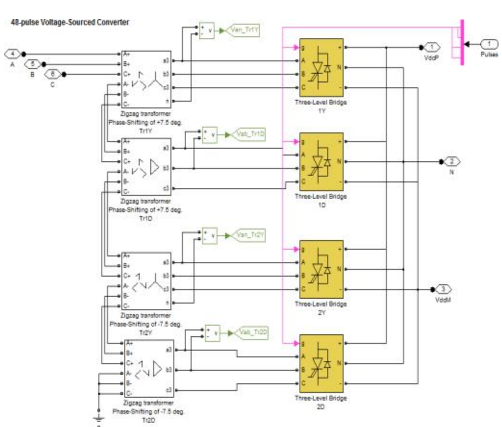

Fig. 8. Simulation block diagram for the E-STATCOM 48-pulse voltage source inverter

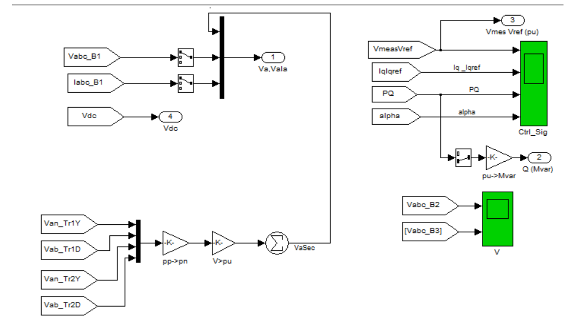

Fig. 9 Simulation block diagram for thecontrol signal and voltage.

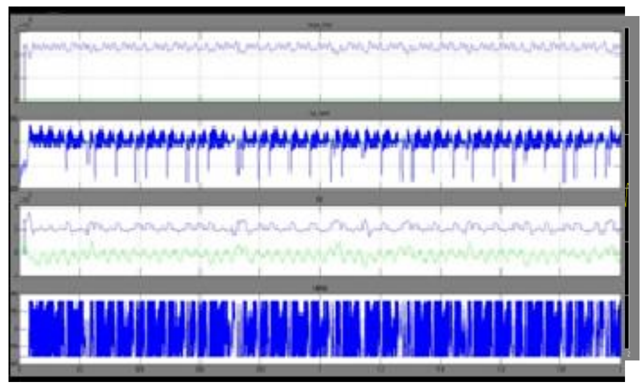

Fig.10. The control signals.

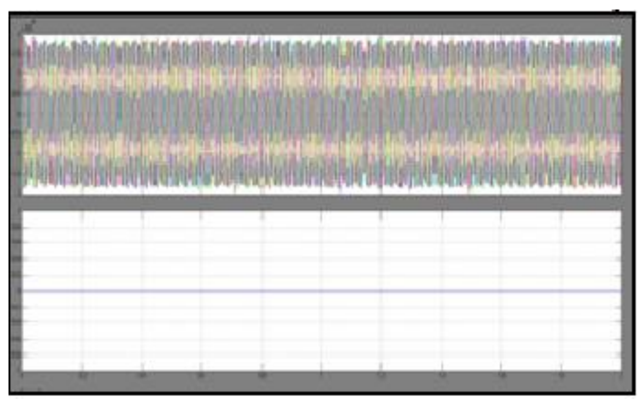

Fig.11. Simulation results for the voltage.

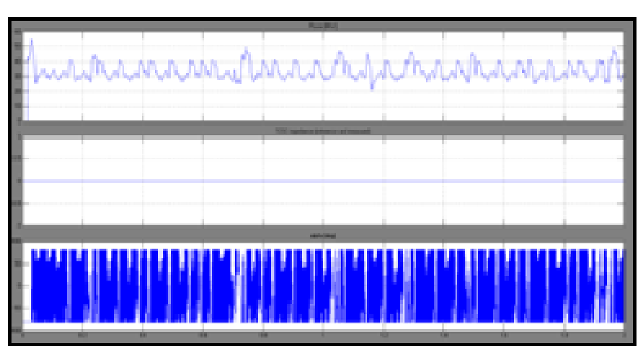

Fig.12. Simulation results for the E-STATCOM.

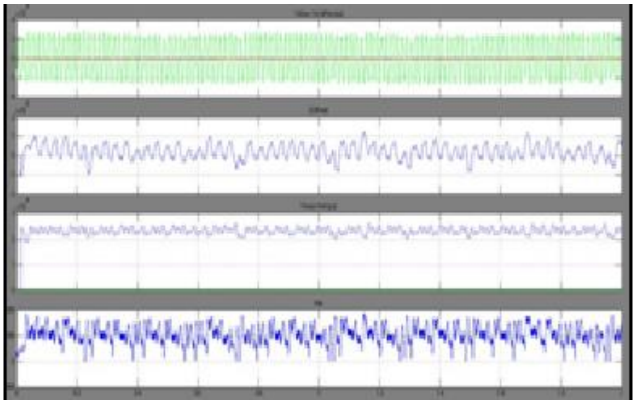

Fig. 13. Simulation results for the power.

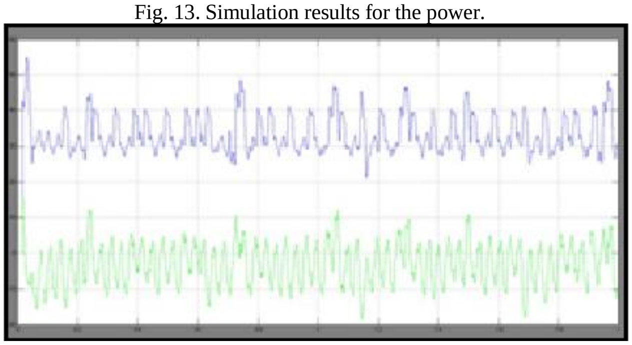

Fig.14. Simulation results for the realand active power.

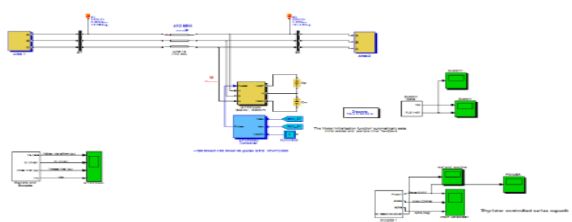

Fig.15. Simulink diagram forthe system with E-STATCOM using PI controller.

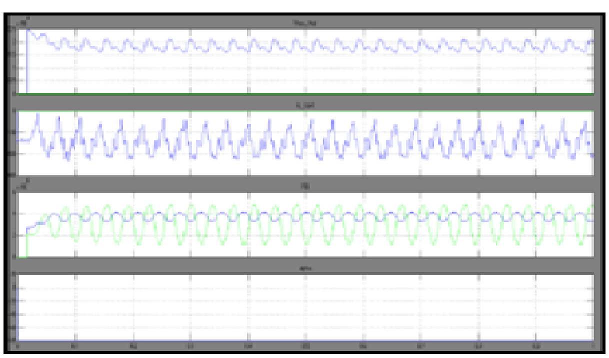

Fig. 16.. Simulation results for the controlsignal.

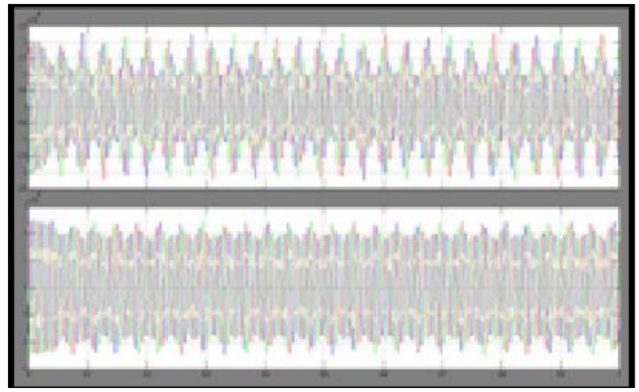

Fig.17. Simulation results for the E-STATCOM using PI controller.

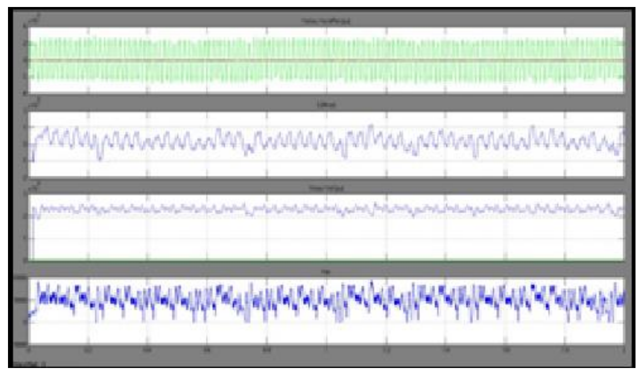

Fig. 18. Simulation results for voltage.

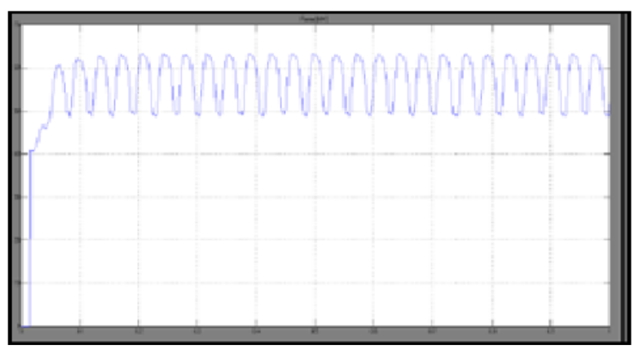

Fig.19.. Simulation results for the realand reactive power.

V CONCULSION

With the POD controller structure the performance of the E-STATCOM following the fault at three different locations, This low oscillation frequency highlights the importance of the adopted estimation method, since the classical approaches based on filters would require low bandwidth, resulting in a reduction in the estimation speed. The small-signal analysis for two-machine system, when moving closer to the generator units, a better damping isachieved by active power injection. With respect to reactive power injection, maximum damping action is provided when the E-STATCOM is connected close to the electrical midpoint of the line and the level of damping decreases when moving away from it. Because of a good choice of signals for controlling both active and reactive power injection, effective power oscillation damping is provided by the E-STATCOM irrespective of its location in theline.

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